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Semi-Annual Status Report

No. 8

for the

6 month period ending 28 February 1966

on

VACUUM ULTRAVIOLET RADIATION AND SOLID STATE PHYSICS

sponsored by the

National Aeronautics and
Space Administration

Grant No. NsG-178-61

submitted by

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10 March 1966

"VACUUM ULTRAVIOLET RADIATION AND SOLID STATE PHYSICS"

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During the last half-year, progress has been made in three separate areas:

I) the optical constants, namely the index of refraction n and the extinction coefficient k, were obtained for many separately deposited barium surfaces and two silver surfaces, all maintained in a vacuum of about 5×10^{-10} torr;

II) the grazing incidence monochromator has provided final measurements of grating efficiencies down to 150 Å; and

III) optical constants of surfaces and thin films maintained in conventional vacua of 10^{-5} torr and measured at grazing incidence down to 150 Å.

The following will provide in somewhat greater detail the progress made in the above three areas.

I. VACUUM ULTRAVIOLET PHOTON INTERACTIONS WITH SURFACES MAINTAINED IN AN ULTRAHIGH VACUUM

During the summer of 1965 a large number of Ba surfaces have been evaporated and maintained under conditions of an ultrahigh vacuum of about 3×10^{-10} torr. For each of these surfaces, reflectance measurements were made in the wavelength range between 1450 Å and 3000 Å. As previously described, this radiation was provided by a near-normal incidence monochromator

operating under conditions of ordinary high vacua, of the order of 10^{-5} to 10^{-6} torr. The ordinary monochromator vacuum was separated from the ultrahigh vacuum by sapphire windows. Reflectance measurements as a function of wavelength in the range indicated above were obtained at two angles of incidence upon the freshly distilled Ba surface: 17.5° and 72°. The trend of the results for this large number of separately measured Ba surfaces indicated clearly which of these surfaces were least contaminated. In addition, this work brought out the fact that a newly evaporated surface would give best results if

a) the substrate was glass, not highly polished stainless steel,

b) if the previous film was removed before the deposit of a new one.

The results have been written up in detail in a technical report which will be ready for distribution in about four weeks from the data of this status report. For this reason, it will not be necessary to include the details of this investigation here.

In addition, a paper has been written on the optical constants of Ba and will be submitted to the Editor of the Journal of the Optical Society of America within one or two days.

In order to provide a check on the new optical constants of Ba and the techniques employed in obtaining them, it was felt worthwhile to investigate in our apparatus Ag, a substance for which a great deal of literature data is available. The silver results checked accurately and closely the best optical

constants for this material reported elsewhere, which further increases our faith in the Ba results. The silver data will not be reported in detail in the paper submitted for publication. However, they will be part of the technical report referred to above.

Both the recent results on Ba and on silver have been reported in a contributed paper at the Meetings of the American Physical Society at the University of California at Los Angeles, December 21-23, 1965, and are listed as a reference at the end of this report.

1) Combination of ultraviolet vacuum reflectometer and ultrahigh vacuum monochromator without windows.

As has been described in some detail in earlier status reports, it is essential to investigate the optical constants of surfaces at shorter wavelengths than those transmitted by sapphire windows. In order to achieve that, the present reflectometer chamber (in which the Ba and silver results have been obtained) will be converted into an ultrahigh vacuum monochromator. This in turn will be optically coupled to a new ultrahigh vacuum reflectometer chamber. Construction of this new reflectometer chamber has been finished, but there are still some minor leaks in it, as indicated on the most sensitive scale of a helium mass spectrometer lead detector. This new reflectometer chamber requires a separate bake-out oven, which has been designed and is now being constructed in the USC Physics Shop. In order to avoid any possibility of organic materials reaching the chamber, it is being pumped out

to fore-vacuum pressures by liquid nitrogen-cooled zeolite sorption pumps. The final ultrahigh vacuum in the 10^{-10} torr range will be achieved by a 400 l/sec ion pump. The mechanical construction of both the fore vacuum and ultrahigh vacuum pumping lines has been completed. After the bake-out oven becomes operational, it is planned to deposit various metal surfaces under conditions of ultrahigh vacua in this chamber in order to determine the best techniques for generating surfaces of highest purity. Such techniques may involve evaporation by use of electron beams in contract to the present methods, in which Ba in evaporated from heated tungsten coils or boats.

II. GRAZING EFFICIENCIES DOWN TO 150 Å

Final data have been obtained on the efficiencies of seven gratings measured down to grazing incidence angles and down to 150 Å. These gratings represent carefully-blazed Bausch and Lomb replica gratings with various surfaces (platinum, gold, and aluminum). The blaze angle involved varied between 1° and $2\frac{1}{2}^{\circ}$. In addition, two Siegbahn-type gratings (lightly ruled on a glass mirror) were also tested. The write-up of this research has been completed and will be submitted within one or two days to the Editor of the journal "Science of Light," Tokyo. Professor M. Seya of Tokyo, has informed me in private communication that he and Professor Namioka have written a theoretical analysis paper on grating efficiencies in the extreme vacuum ultraviolet region of the spectrum. Both his theoretical article and ours on the experimental

grating efficiencies will hopefully appear in the same issue of the above referenced journal. If time is available, a technical report will be issued, duplicating the paper.

III. OPTICAL CONSTANTS OF SURFACES AND THIN FILMS MAINTAINED IN CONVENTIONAL VACUA OF 10^{-5} TORR AND MEASURED AT GRAZING INCIDENCE DOWN TO 150 Å

Again, earlier reports have described a separate program in which, under conditions of conventional vacua of 10^{-5} torr, the optical constants will be measured simultaneously with the photoelectric yields and with the energy distribution of the emitted photoelectrons. In brief, self-supporting thin films will be employed as target materials. The optical constants, reflectance and transmittance, can be determined for these films. If the photon flux emerging from the exit slit of the grazing incidence Vodar monochromator is known, then the number of photons absorbed in the thin film can be calculated and related to the total number of photoelectrons emitted from both sides of the film.

One of the difficulties at the short wavelengths is the determination of the absolute photon flux in units of photons per second. This requires very high intensity light sources and special detection techniques. Our development in both areas has been reported in an invited paper at the International Conference on "Optical and Spectroscopic Instrumentation" in Tokyo and Kyoto, September 1 to 8, 1964. This material has also been published in the Japanese Journal of Applied Optics and is

referenced at the end of this report.

In addition, preliminary results of photoyields from thin films have been measured and reported as a contributed paper to the University of California at Los Angeles Meetings of the American Physical Society, December 21-23, 1965. This is also referenced at the end of the report.

IV. MOVE OF RESEARCH FACILITIES INTO NEW PHYSICS BUILDING

At the time of this writing the move of the existing research equipment into a new building, Stauffer Hall, has been nearly completed. The word 'completed' here is meant to indicate that the apparatus is now at its new location. However, a tremendous amount of work is required in order to reconnect all experiments and have the apparatus begin to function so that new results can be obtained. Some of this will go faster than others. Nevertheless, it is hoped that all of it will be operational by the beginning of summer, 1966.

V. PROPOSED RESEARCH DURING THE FORTHCOMING SIX-MONTH PERIOD

1) <u>The optical constants of ultrahigh vacuum deposited surfaces between 1500 and 3000 Å</u>.

Initially it is planned to follow the procedures established for Ba (as outlined above) for the following materials:

Lithium, 8.1 eV energy loss,
Sodium, 6.0 eV energy loss,
Potassium, 4.4 eV energy loss,
Rubidium, 4.0 eV energy loss,
Caesium, 3.6 eV energy loss.

Some of these materials, particularly lithium, may exhibit too high a chemical reactivity, even under conditions of ultrahigh vacua, to warrant extensive investigations. However, one or two of these metals should lend themselves to the type of experiment described for Ba. This procedure will not only obtain new results on some new elements, but it will also serve as a test that our apparatus is functioning properly in its new location. As soon as we can be assured of this, the following new experiments will be initiated.

2) Combination of ultrahigh vacuum monochromator and reflectometer without sapphire windows.

It is hoped that the coupling of these two instruments will be initiated sometime at the end of the summer of 1966 or during the fall of 1966. This arrangement will make it possible to determine the optical constants down to a wavelength of about 800 Å or perhaps even 600 Å. This short wavelength region is of particular significance, since the plasma frequencies of most metals (with the exception of the alkalies mentioned above) lie in this part of the vacuum uv spectrum. No work has as yet been done on the optical constants in this wavelength region under ultrahigh vacuum conditions. We look forward with great anticipation to exploring this virgin field.

3) Optical constants, photo yields, and photoelectron energy distribution down to 150 Å.

As soon as the apparatus becomes functional again in its new location, this work will be continued along the lines

described above. In addition, it is hoped to manufacture in our laboratory some single crystal thin films in order to relate the direction of the emitted photoelectrons with the crystal structure and with the plane of polarization of the electric vector of the radiation incident upon such thin films.

Finally, the thin film reflectometer chamber will have coupled to it not only the Vodar grazing incidence monochromator (75 Å to 1000 Å), but will also be coupled to a Seya monochromator (300 Å to 10,000 Å). The use of these two monochromators in conjunction with the same reflectometer chamber will make it possible for the first time to measure on one and the same thin film the following quantities nearly simultaneously and over a range from 100 Å to 10,000 Å (equivalent to 120 eV and about 1 eV):

a. reflectance,
b. transmittance,
c. photoelectric yield,
d. photoelectron energy distributions,
e. polarization (vectorial) effects,
f. crystal structure of the film.

It is hoped that work in this direction will get under way during the next report period.

VI. PUBLICATIONS

1. "Some Instrumentation Problems below 1000 Å," G. L. Weissler, ICO Conference, Tokyo, Sept. 2-8, 1964; Japan. J. Appl. Phys. 4 (Supplement I), 486 (1965).
2. "Optical Constants of Barium and Silver in the Vacuum Ultraviolet," E. I. Fisher, L. R. Whalley, and I. Fujita, Bull. Am. Phys. Soc. 10, 1185 (1965) (F2).

3. "Photoemission from Al Films in the Extreme Ultraviolet," A. L. Morse and J. E. Rudisill, Bull. Am. Phys. Soc. 10, 1186 (1965) (F10).

4. "Optical Constants and Photoelectric Yields in the Soft X-Ray Region," G. L. Weissler, invited paper to the International Conference on the Physics of X-Rays, Cornell University, June 22-24, 1965; Bull. Am. Phys. Soc. 10, 1224 (1965).

5. "Optical Constants of Ba in the Vacuum Ultraviolet," E. I. Fisher, I. Fujita, and G. L. Weissler, J. Opt. Soc. Am; submitted for publication March, 1966.

6. Technical Report on 5. above.

7. "Grating Efficiencies at Grazing Incidence in the Extreme Vacuum Ultraviolet Region," A. L. Morse and G. L. Weissler, Science of Light, Tokyo; submitted for publication March 1966.

25 copies respectfully submitted,

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NASA Grant No. NsG-178-61

10 March 1966